9th Microoptics Conference (MOC'03), Tokyo, Japan, October 29-31, 2003

G3

Fabrication method of Double Micro Lens Array using Self-Alignment Technology

K.Kitamura,K.Okada,N.Fujita,Y.Nagasaka,M.Ueda,Y.Sekimoto,Y.Kurata
Precision Technology Development Center ,SHARP Corporation
2613-1 Ichinomoto-cho,Tenri-shi,Nara 632-8567,Japan
Phone:+81-743-65-2462,Fax:+81-743-65-3216,E-Mail:kitamura.kazuya@sharp.co.jp

Abstract: A fabrication method of Double Micro Lens Array with Self-Alignment Technology process is proposed. To satisfy the tolerance of the alignment of two layer lens array, we developed a new fabrication method without alignment process. Using SAT process, we achieved a brightness increase of 30% compared to conventional single layer micro lens array.

1. Introduction

In the large-sized display of a rear projection system using the high definition LCD(Liquid Crystal Display), reduction of panel cost and the improvement in the brightness of the screen are most important subjects.

Since in the conventional 3-LCD(3 boards LCD) projector, 3-LCD corresponding to R, G, and B each color are used, the rise of cost is not avoided. In the single-LCD projector, because of using a color filter, the decrease in the brightness poses a problem.

Then, the rear projector of the new single-LCD system which does not use a color filter is proposed. [1]

In this system called Colorfilterless Single-LCD Projection System, by using dichroic mirrors, white light is decomposed into three colors, R, G and B, and it distributed to each pixel (see Fig.1).

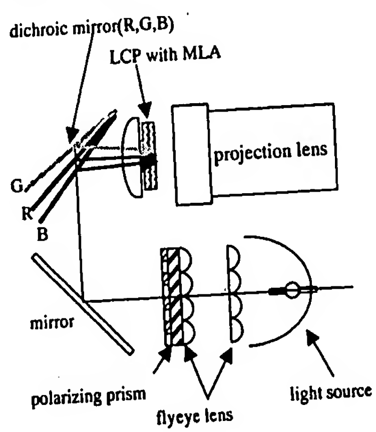

Fig.1.Schematic of the Colorfilterless Single-LCD Projection System

Since color filters are not used in this system, it has the brightness about 3 times that of the single-MLA projector with color filters. But the further improvement in the brightness is the most important subject.

In this time, in order to raise the brightness of the Colorfilterless Single-LCD Projector, we proposed that two layers MLA(Micro Lens Array) united with a LCP(Liquid Crystal Panel). We developed new processing technology for two layers MLA (D-MLA;Double Micro Lens Array). We call this processing technology SAT (Self-Alignment Technology) process.

In this paper, SAT process for D-MLA is reported.

2. Design

The structure of the D-MLA is shown in Fig.2. In this D-MLA which consists of two layers, the 1st.MLA is arranged to a light source side, and the 2nd.MLA is arranged near the black matrix layer. The focal point of the 1st.MLA is near the black matrix.

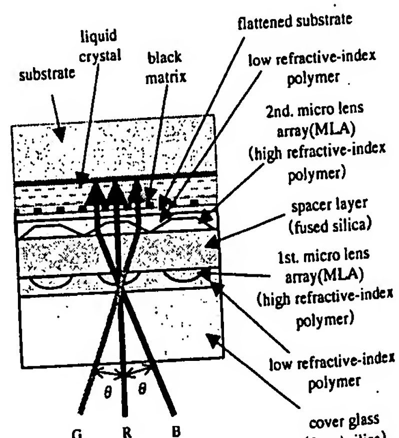

Fig.2.Layer structure of the D-MLA

The parallel pencils of rays incident to the 1st.MLA is focused on the black matrix. The chief ray of R light is perpendicular to the LCP, and the chief rays of G light and B light have angle θ to the LCP. By 2nd.MLA, the chief rays of G light and B light are refracted parallel to that of R light. So the chief ray of each color of R,G,B become parallel one another, and perpendicular to LCP. For this reason, the pencils of rays of R, G and B incident to the projection lens is not blocked by the projection lens, and it is evenly colored.

The 1st.MLA has the honeycomb structure. The layout of the 1st.MLA, the 2nd.MLA and the pixels are shown in Fig.3.

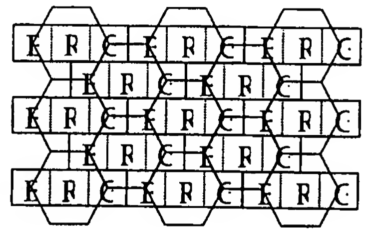

Fig.3. Layout of the 1st.MLA, the 2nd.MLA and the pixels

The oblique angle of the 2nd.MLA is depend on the difference of refractive-index between the high refractive-index polymer and the low refractive-index polymer, and the incident angle to the 1st.MLA of the chief ray of G and B. The oblique angle of the 2nd.MLA is 50°, on that occasion brightness is maximum.

The larger the difference of refractive index of these two polymers is, the smaller oblique angle of the 2nd.MLA is. Therefore, the aspect ratio of the height of the 2nd.MLA and the length of basal plane of this become small, and processing is easy. Here, we thought reliability and process ability as important, we decided to use these polymers.

Specification of the oblique angle of the 2nd.MLA is 50°±5°.Then the chief rays of G and B change the angle about 2.7°, but it is small angle compared with the angle of the chief rays of G and B incident to the 1st.MLA (see Table.1).

Table.1.Design of 2nd.MLA

oblique angle of 2nd.MLA	angle of side-wall	height of 2nd.MLA
50°	more than 80°	$25\mu m$

We decided the target of the efficiency of the D-MLA was 1.3 times compared to that of single-MLA in consideration of the fabrication tolerances and the variations in this process.

3. Self-Alignment Technology

The important points of the processing the 2nd.MLA are shown below. The first point is that the angle of side wall is near 90°. The second point is that the alignment accuracy between the 1st.MLA and the 2nd.MLA is correctly.

If the photo-polymer processing method using the stamper is used, the disadvantage will arise on the point shown above. That is, about the first point, the stamper needs the angle about 15° for the form and size of the 2nd.MLA, and about the second point, it is very difficult to set the 1st.MLA and the 2nd.MLA with accuracy, with the $100\mu m$ spacer-layer inserted. So we developed the new processing method about the 2nd.MLA without complicated alignment process.

This processing method is called the Self-Alignment Technology (SAT) process, that is, the 2nd.M[illegible] formed at the focal point of the 1st.MLA u[illegible] focusing property of it. The Schematic of th[illegible] process is shown in Fig.4. The i-line(λ=365nm) for the exposure made into the parallel light, and this parallel light is incident to the 1st.MLA by 0° incident angle, a condensing point arises at the point O which is a near focus.

This point O corresponds with the optical axis of the 1st.MLA. The next step, the 1st.MLA is rotated δ degrees together with the substrate, and then condensing points arise at the point P which is corresponding to the incident angle δ. At this time, if the focal length of the 1st.MLA is set to f, the following formula will be realized.

$OP = f \cdot \tan\delta$

From this relation, if we intend to expose the resist on P with thickness asking for, we should irradiate it with incident angle δ by the necessary exposure dose.

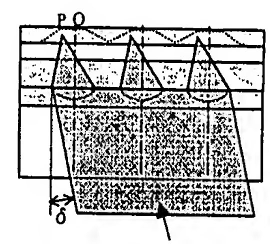

Fig.4. Schematic of the SAT process

On the other hands, the negative-resist shown in Table.2 was used. This negative-resist was chosen from the following reason. The first reason is the height of the 2nd.MLA is very high, that is, $20\mu m$ or more required. The second reason is the negative-resist needed to be

G

cured on the focal point of the 1st.MLA, because of the form of 2nd.MLA shown in Fig.4.
The relation between the negative-resist thickness and the exposure dose is shown in Fig.5. The negative-resist thickness increases with the exposure dose. From this result, it is possible to control the negative-resist thickness by changing exposure dose.

Table.2. Specification of the resist

Resist	Negative-resist
Viscosity	1600CPS
Exposure Sensitivity	200～400mJcm-2 (@405-420nm)
Resolution(Line/Space)	20/20μm
Thickness of resist	32μm
r.p.m. of spincoater	1150rpm

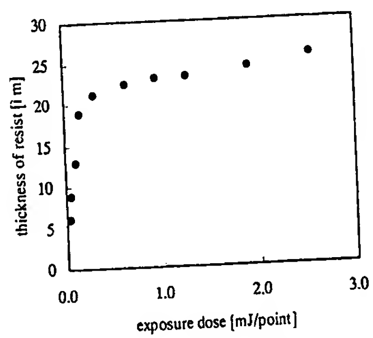

Fig.5.Dependence of the thickness of the negative-resist on the exposure dose

The resist pattern after development of the cross-section seen from the longitudinal direction of the 2nd.MLA is shown in Fig.6. The oblique angle achieves the design value 50°.
On the other hands, the resist pattern after development of the cross-section seen from the right angle to the longitudinal direction of the 2nd.MLA is shown in Fig.7. The angle of side-wall is more than 80°.

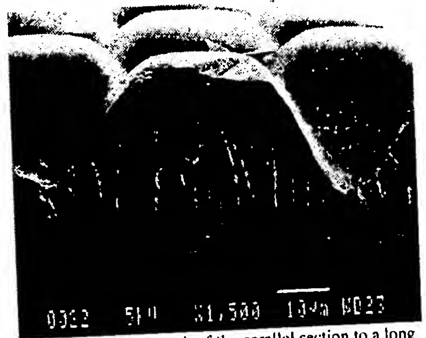
Fig.6.SEM photograph of the parallel section to a long side of the 2nd.MLA


Fig.7.SEM photograph of the perpendicular section to a long side of the 2nd.MLA

4. Fabrication

This process flow diagram is shown in Fig.8. At the first, the 1st.MLA is formed by the 2P (photo-polymer) method using the stamper made of silica. Next, the spacer-layer is stuck on the 1st.MLA. The spacer-layer is lapped and polished in predetermined thickness, and the high refractive-index polymer as material of the 2nd.MLA is applied on the spacer-layer, and furthermore, the negative-resist is applied on it. Then, this negative-resist is exposed for the form of the 2nd.MLA according to the SAT process. After exposing, this form is transferred to the high refractive-index polymer by dry etching and the flattened substrate is stuck using the low refractive-index polymer on the 2nd.MLA and the flattened substrate is lapped and polished in predetermined thickness, and the black matrix layer is formed on them. Thus, the substrate of the liquid crystal panel is completed. In the substrate of the liquid crystal panel, forming the transparent electrode layer and the orientation layer etc. if need and joining to TFT base plate, liquid crystal is infused between them, and then the liquid crystal panel is completed.
The 1st.MLA after the 2P method seen from the top is shown in Fig.9. This form is honeycomb structure as

above mentioned, and the gap between lenses is good at 0.5μm or less.
As a result of measuring, we found that the efficiency of the D-MLA increased by 30% compared to that of Single-MLA.

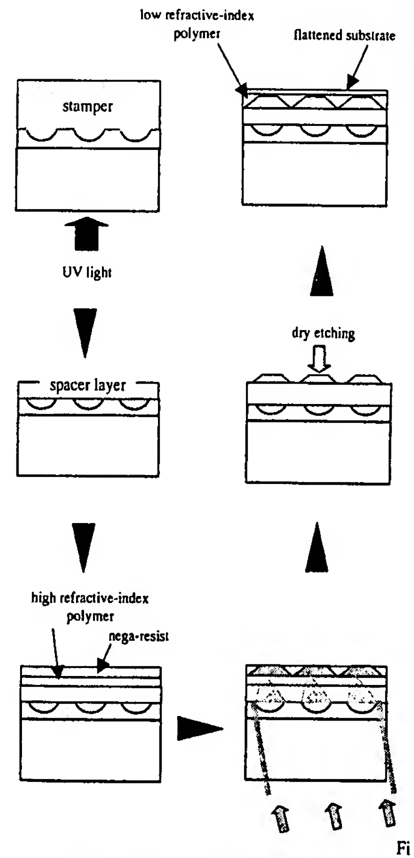

Fig.8.Fabrication process of the D-MLA

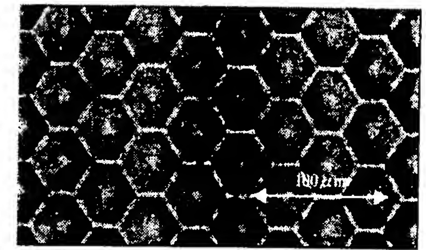

Fig.9. Microscope photographs of the 1st.MLA

5. Conclusion

We developed the processing technology of D-MLA. Using this technology, we are able to fabricate any three-dimensional shape and achieve easy alignment and good accuracy.
We obtained the 2nd MLA which has the oblique angle of 50°, the angle of side wall of 80° or more and the aspect ratio 1.2 (narrow side).
This new technology expands the possibility of processing of optical elements which needs large aspect ratio and severe alignment accuracy, and it is useful to various micro optical elements.

6. Acknowledgment

The authors is grateful to Mr. H.Hamada and the members of SD-PT of Sharp corporation for the helpful discussions and insights.

7. Reference

[1]H.Hamada et al., "A new bright single panel LC-projection system without a mosaic color filter," IDRC '94 DIGEST pp.422-423 (1994)